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## SOME CONSIDERATIONS REGARDING SO-CALLED FORMATIVE SUBSTANCES.

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Within the last few years the idea of "formative substances" has received consideration and support from workers in certain fields of zoölogy and embryology to such an extent that it appears worth while to examine critically some of the assumptions upon which the hypothesis of the existence of such substances rests.

As the first step in this consideration a definition of formative substances is necessary. But anything like an exact definition is difficult to find even in the literature which has devoted most attention to these hypothetical substances. We read of ectodermal substance, myogenic substance, hydranth-forming substance, head- and tail-forming substances, etc., but the general question, what is a formative substance? does not seem to be very clearly answered. It may, however, be inferred from the use of the term that a formative substance is a specific substance capable of giving rise under certain conditions to a specific structure. Secondly, we must inquire as to the nature of organic structure to which these formative substances are supposed to give rise? Organic structure may be defined as a complex of heterogeneous parts of typical constitution and arranged in typical space relations. Strictly speaking this definition is not exact, for organic structure, like other kinds of structure, is fundamentally simply a matter of space-relations or arrangement of parts entirely independent of their constitution. The constitution of the component parts must of course play a rôle in determining the dynamic or functional activities of the structural complex, and ordinarily we do not

clearly dissociate the idea of organic structure from the dynamic activities which it exhibits. For the sake of critical analysis, however, it is necessary to emphasize the fact that organic structure is primarily a typical arrangement of heterogeneous components without regard to their constitution. This becomes evident at once from the following consideration: if each component of a given organic structural complex could be distinguished it would be possible to build up artificially an identical structure in which each component was different in constitution from the corresponding component in the original structure. On the other hand, if all the different components of an organic structural complex could be isolated without altering their condition and then mixed together the mixture would not represent the original structure.

It thus becomes evident that the space-relations of the components, not their constitution, are the characteristic feature of structure proper. From this conclusion it follows that formative substances, if they exist, must be specific substances which determine the arrangement of the component parts of a structural complex. In order to determine whether formative substances do exist we have first to consider the possible methods of origin and action of such substances. As regards the individual, for example, each substance must either be represented in the primitive germ-cell by an ultimate "unit of organization" of the same nature as itself, or it must have arisen from other substances in the course of development.

In the one case development is merely the "unfolding," "activation," or whatever we prefer to call it, of preformed "germs," "determinants," or "definite, determinate and primary" units of organization. In the other case it is, properly speaking, an epigenesis, in the course of which new formative substances appear as the result of the activity of others, and the complexity of the developing organs increases.

Directing our attention first to the preformation hypothesis we must inquire as to the nature of these ultimate units which represent both the formative substances and the structures of later stages. Are they simply molecules or groups of similar molecules, or are they something more complex?

## Ultimate Units Molecules or Groups of Similar Molecules.

If the ultimate units are molecules or groups of like molecules, then their properties as formative substances must be the result of their physical and chemical properties as molecules. If this be admitted the hypothesis based on these assumptions is identical with or similar to the crystallization hypothesis. For structure is primarily a definite and characteristic space-relation of parts and an aggregation of like molecules cannot, so far as we know, give rise to anything like definite and characteristic fixed space-relations except by an arrangement of its molecules according to physical laws. According to this view organic structure is made up of a multitude of component parts, each consisting of like molecules, but each different from the others in composition and each arising from its corresponding ultimate unit. But in the fully developed structure these different components are definitely arranged, and indeed it is this feature — the definite space-relations of heterogeneous parts — that is the fundamental characteristic of all structure. To what is this arrangement due? If we say it is due to the physico-chemical interactions and relations to each other of the substances in a given environment, then we have departed from our premises, for in this case the relations and the environment are more directly and immediately formative factors than the substances. The substances have formed the various components, but there is no substance which can be made to account for their arrangement.

If, on the other hand, we assume that the characteristic arrangement of the heterogeneous parts is due to something else than their physico-chemical interactions and relations in a given environment, then we pass beyond the realm of physics and chemistry and become "vitalists."

In short if we start from a series of molecules or groups of like molecules as the ultimate formative substances, we can, by assuming a process of crystallization or something similar in each substance, account for the development of each physico-chemically homogeneous element of structure, but we cannot account for the most important feature of structure, *viz.*, the characteristic arrangement of heterogeneous elements except by assuming rela-

tions and interactions as the formative factors or by adopting a vitalistic point of view. In any case the formative substances are inadequate to produce the observed result.

But the crystallization hypothesis has found no wide acceptance. Most authorities agree that the process of formation of the various parts of organic structure is at least in most cases either only very remotely similar to the process of crystallization or differs totally from it. It may be that in certain cases the process of morphogenesis is akin to crystallization but the results of experimental work demonstrate that in very many cases it certainly is not.

### Ultimate Units Groups of Dissimilar Molecules.

The other alternative under the preformation hypothesis, *viz.*, that which assumes the ultimate units or formative substances to be something more than molecules or groups of like molecules, also presents certain difficulties.

These complexes must be either simply physical mixtures or complexes or they must be molecular complexes of some other kind.

If we consider them as physical complexes then their formative activity is the result of the relations between parts or of these relations plus a given environment, *i. e.*, none of the substances can be regarded as in itself formative but only the complex as a whole or the complex plus the environment.

Now if the formative substance is a mixture or other physical complex whose activity depends only or primarily on relations between its parts why does its activity appear only at a certain time? If we admit that the environment, *i. e.*, relations with other elements, etc., play a determining rôle then these relations are just as truly formative as the complex on which they act. Moreover, as in the case considered under the previous heading we must either assume that the characteristic arrangement of the elements in developed structure is due to physico-chemical relations between the different complexes or we must take refuge in vitalism. But let us assume that the ultimate element is a complex of molecules of some other sort, *i. e.*, that it possesses a certain "organization." Physics and chemistry recognize at

present no such organization of dissimilar molecules. Thus we are again in danger of being regarded as vitalists. Even if we assert that this organization is finally reducible to a physico-chemical basis we cannot show how it is reducible. In any case we are adopting a position for which the facts afford no warrant; moreover, we are assuming in our hypothesis exactly that which the hypothesis is supposed to explain, *i. e.*, we postulate one organization in order to explain another. Naturally if organization forms the basis of the hypothesis no real difficulties will be encountered in individual cases for we can refer them at once to the hypothetical organization. One frequently reads that a considerable degree of organization is necessary for the phenomena of life, that protoplasm possesses a high degree of morphological organization, etc. The authors of these statements do not always inform us as to the nature of this organization, but there is, I think, no escape from the conclusion that unless we admit that a molecule or a physical complex of molecules can exhibit the phenomena of organic life our hypotheses are open to the objections stated above.

In his earlier work Weismann designated the ultimate units postulated in his hypothesis as molecules but later asserted that they are not molecules in the physical sense, but consist of a number of such molecules. Unless these complexes are purely physical, and so far as I can determine, Weismann does not seem to regard them as such, his hypotheses is open to these same objections. Other similar "organization" hypotheses are in the same position.

## The Hypothesis of Epigenetic Origin of Formative Substances.

If a development of new formative substances from previously existing substances occurs during development we come ultimately as regards ontogeny to the primitive germ-cell which must be composed either of a formative substance or of a complex of substances from which the substances appearing in later stages arise. At the present time probably no one would regard the primitive germ-cell as containing only a single formative substance but such a hypothesis would be a contradiction in terms

since the real formative activity would in this case reside in the environmental conditions not in the substance.

Assuming then that the primitive germ-cell contains a complex of formative substances all that has been said in the discussion of preformation hypothesis regarding the nature of ultimate units of organization would apply here. The complex must be physico-chemical in nature and the formative factors must reside in the relations between the constituents of the complex and in the environment, not in the single constituents themselves, for a single substance cannot of itself give rise to unlike substances, definitely arranged.

Most hypotheses of this character assume further that the elements of this ultimate complex are definitely and characteristically arranged. This arrangement must be the result of physico-chemical conditions past or present, *i. e.*, the cause of the organization is to be found in relations not in particular substances, or else we must again take refuge in vitalism and assume the existence of some organizing principle ultra-physico-chemical in nature.

The next question to be considered is — how do the new formative substances which appear at any given stage and in typical space relations arise from those previously existing? Here again we must point to the physico-chemical conditions in the complex, *i. e.*, to the relations and interactions of the elements in a given environment as the real formative factors, since a single substance cannot of itself give rise to unlike substances in typical space-relations.

And finally, how do the last series of formative substances give rise to the definitive structures? Here three points of view are possible. We may assume as in the preformation hypothesis a process of crystallization or something similar but by so doing we account only for the form of the elements of structure not for the characteristic arrangement of these elements. We may attempt to account for this by assuming that the formative substances existed in a similar characteristic arrangement, but this only throws the difficulty back to earlier stages. We must turn sooner or later from substances to relations or else to vitalistic assumptions. Secondly we may assume some grouping principle

of unknown nature — again a vitalistic conception — or finally we must admit that the relations not the substances give rise to the final arrangement of parts.

THE RÔLE OF CHEMICAL CONSTITUTION IN MORPHOGENESIS.

Objection may be made to the conclusions reached above on the ground that the chemical constitution of the various substances plays a part in determining the character of the relations which exist between them, and consequently in determining the character of the result. It is of course quite true that the chemical constitution of the substances involved may affect the result, but a single substance can accomplish nothing of itself by virtue of its composition. It must enter into relation with another or others in a more or less typical environment and the composition of the other substances and the factors of the environment are equally important in determining the result. What are the real formative factors in this case? It is evident that we can properly recognize only a formative complex of substances and relations and in this complex the constitution of the various substances is a condition affecting the character of the result while the relations between the substances are the cause of the result. But again it may be objected that the chemical constitution is the cause of the relations existing. While this may be true in large measure for certain simple chemical reactions it certainly is not true for many of the processes which give rise to organic structure.

Many other conditions beside those resulting from chemical constitution are usually important. For example, we know that the formation and persistence of various structures is determined primarily by simple mechanical conditions. It may be said that these conditions are not effective unless they act upon a particular substance but unless we make the term particular substance equivalent to protoplasm of a particular species or genus there is no evidence that this is true.

There is very strong evidence for believing that mechanical conditions resulting from the presence of fluid in a cavity are often fully as important as the character of the cells about it in determining the development of hollow, fluid-containing structures. We know that mechanical conditions are potent factors in the de-

velopment of bone and connective tissue and many other similar cases might be mentioned. It is conceivable that in some formative processes the most important conditions are chemical relations, but even in such cases the chemical constitution of a given substance is only indirectly "formative."

Moreover, in many other dynamic phenomena occurring both within and outside of the organism the chemical composition is of little importance. The catalytic activity of colloid solutions of metals does not appear to differ fundamentally from that of enzymes and yet the substances involved are widely different; in many of the effects produced by electrolytes one chemical element or radical may be substituted for another without altering the result: compounds of widely different chemical composition may produce identical osmotic phenomena, etc. In short, chemical constitution is at best only one of a large number of factors involved and often is of little or no importance.

Morphogenetic properties have been assigned by various authors to specific enzymes and to other substances of more or less definite chemical constitution. For example, in a recent paper [1] L. Loeb makes the following statement: "Ferments produce primarily chemical changes. But we know of chemical ferment actions which bring about structural changes in the medium in which they act. Thrombin in transforming fibrinogen into fibrin changes a colloidal fluid into a gelatinous, more or less solid mass, which under the influence of pressure and traction may show a fibrillar structure not unlike connective tissue. From a certain point of view the fibrin ferment may therefore be regarded as a form-producing ferment. We might call it a morphogenetic ferment. We have reason to assume that there exist other morphogenetic ferments" (p. 150).

A critical examination of this statement will at once render it evident that the real formative factors in the production of the fibrillar structure are the pressure and traction, and not the enzyme. The enzyme simply changes the condition of the medium in which it acts in such manner that pressure and traction produce a visible structural effect. But the enzyme itself is not properly speaking morphogenetic. The other cases

[1] Immunity and Adaptation. BIOL. BULL., Vol. IX., No. 3, 1905.

of so-called morphogenetic enzymes seem to be similar to this one in that the structure appears, not as the result of enzyme action, but in consequence of certain physical conditions which may accompany or follow the enzyme action but are not an essential part of it. There is nothing specific in the relation of this process to the enzyme. Coagulating or coagulated colloids may be made to assume a fibrillar structure in many cases "under the influence of pressure and traction" in total absence of enzymes. The specific effect of the thrombin and of other enzymes as well has not in any case been shown to be morphogenetic in character.

In general, physical conditions appear to be more important factors in morphogenesis than substances of particular chemical constitution.

## Formative Substances in Ontogeny.

The chief reason for the consideration recently accorded to this old idea of formative substances appears to lie in the fact that many eggs exhibit visibly differentiated regions which normally give rise to particular structural complexes. Moreover, experiment has demonstrated that in some cases certain of these regions are capable of continuing the process of visible differentiation in a manner apparently normal after separation from other parts of the egg or embryo. The conclusion in such cases is that these regions must contain a certain substance or certain substances which are responsible for the differentiation. Hence these hypothetical substances are called formative. These regions are mostly extensive and give rise in development to a multitude of structures : for example we read of ectodermal formative substances, neurogenic substances, myogenic substances, entodermal substances, etc. In some cases, however, smaller regions giving rise to definite organs or parts of organs appear to possess in greater or less degree the power of "self-differentiation." We must regard these regions from either the preformation or the epigenetic point of view, *i. e.*, each element of the structure to which they finally give rise must be represented by an element existing before visible differentiation or else new elements must arise in the course of development. In any case the region must

be a complex. All that has been said above regarding complexes of substances applies here. The result produced is the result of the sum total of conditions existing in the complex. When we assume that the result is due to the presence of certain specific substances in the complex which manifest themselves in a peculiar "formative" fashion we are not only making an inference not warranted by the facts, but we are involving ourselves in various difficulties which become manifest only on careful analysis. Some of these I have endeavored to point out above. All the substances in the complex are or may be formative, and under certain conditions the region gives rise to a characteristic differentiation. But if all the substances are formative the distinction of formative substances is entirely unnecessary and we must regard the region merely as a formative complex.

But it may perhaps be maintained that the formative substance hypotheses do not differ essentially from this since the formative substances are really complexes, not definite chemical substances. If this is the case then it is certainly preferable to avoid the use of the vague term substance in this connection, especially since "formative" factors are known in many cases to be related to substances only very indirectly. Moreover, it is difficult to understand the grounds for distinguishing a particular complex either of substances or of conditions as formative since this implies that others are not formative. The only conclusion justified with regard to "self-differentiation" in isolated blastomeres or egg-regions is that the conditions for the observed differentiation reside in the part. This, however, is really quite different from the conclusion that the piece contains certain formative substances for the particular structures to which it gives rise. The region may differ chemically in greater or less degree from other regions of the egg and this difference may be more or less closely related to the structural result and to that extent formative. But to dignify the chemical peculiarity of a region by the term formative substance involves unwarranted assumptions. The strongest evidence in support of formative substance hypotheses is found in these cases of ontogenic self-differentiation of parts and this, as has been seen, is far from conclusive.

In order to avoid misconception it should perhaps be stated

positively that the writer's position does not at all involve a denial of the clearly demonstrated fact that these regions are different or have become different from others in the egg or embryo, nor does he underestimate the value of the observations which have directed attention to this fact. But to say that these regions contain specific formative substances is to say too much, for the visible differences do not necessarily stand in direct relation to their formative activity. The same "kind" of protoplasm is certainly capable of widely diverse formative reactions under different conditions and the determining conditions are demonstrated in many cases to be dynamic rather than substantial. It seems more nearly correct therefore to maintain that particular lines of activity have been initiated in these formative regions in consequence of past or present conditions and may continue even after isolation of the regions. That different substances exist in the egg and embryo is also clearly demonstrated, but to assert that these are formative or that their presence indicates the existence of particular formative substances is quite another matter, and as the writer believes, not justified by the facts. Should we not therefore be content in view of the facts to designate these so-called "formative" or "morphoplasmic substances" merely as cytoplasmic differentiations, leaving the question as to the nature and significance of the differentiation. open?

## Formative Substances in Regulation.

The attempt has recently been made by Morgan[1] to account for certain phenomena of regulation, especially those connected with polarity by postulating the existence of formative substances. This hypothesis is selected for discussion since it is the latest attempt to interpret formative processes in this manner. Other similar hypotheses are, however, open to most of the same objections. In addition to the objections discussed above to which the idea of formative substances in general is open there are certain other objections which apply specially to the application of this idea to the phenomena of form-regulation.

It is of interest to note first that these formative substances are quite different from those of the embryologists. Here for exam-

[1] *Science*, XX., December, 1904. *Journ. Exp. Zoöl.*, I., 1904, and II., 1905.

ple instead of ectodermal, neurogenic, myogenic, mesenchymal, entodermal, substances, etc., we have head-forming and tail-forming substances, pharyngeal substances, hydranth-forming material, stolon-forming material, etc. How do these substances arise from the substances supposed to exist in ontogeny. A head or tail of a planarian or the hydranth of a hydroid is a very complex structure which has developed from regions more or less widely separated in the egg. Is the head-forming substance made up of all the different substances which were concerned in the original development of the head or is it something new? If it is the sum total of the ontogenetic substances then it must in itself be organized, *i. e.*, the different parts of which it consists must possess characteristic positions with reference to each other and we have another organization to account for. Moreover, why should such an enormous amount of head- and tail-forming substances as must exist for example in planarians be left over after development is completed? What is their function in the normal animal or are they without function? If the latter is the case it looks very much as if provision were made in the normal animal for regulation, in other words as if regulation might be after all an adaptation.

Polarity is regarded as identical with a postulated gradation of the various materials. The head-forming materials in planarians, for example, are supposed to decrease from the anterior end backward, the tail-forming materials in the opposite direction, the pharynx-forming material from the middle toward both ends, etc. This idea followed to its logical conclusion certainly does not assist us in comprehending organic structure, but rather increases the difficulty. How did this gradation come about and why should it exist? As we have seen, the various head-forming substances were widely separated in the egg. How and why have they combined in this peculiar manner? Why does not a small piece from the region of the body just behind the head in *Planaria* always give rise to heads at both ends, since the head-forming substance is greatly in excess at both ends as compared with the tail-forming substance? Why does not the pharynx in such a piece arise at the extreme posterior end since the pharynx-forming substance is more abundant there than elsewhere in the piece?

In considering the case of *Tubularia* Morgan[1] makes the following statement which may perhaps serve to illustrate the nature of his hypothesis: "We may assume that the gradation of the material is of such a kind that the hydranth-forming material decreases from the apical toward the aboral end. The formative influence acting from the exposed end inward (the stimulus of the water on the free end), finds a prompter response when it acts in the direction of decreasing amounts of hydranth-forming material (which has the same gradation as that in the hydranth itself) than when acting in the reverse direction (namely at the aboral end). Therefore the oral polyp, as a rule, develops first. For its development it needs certain nutritive material. This it finds either in the cœnosarc or in the circulation, and uses the materials as it develops. In consequence the cut surface at the basal end cannot get the material necessary for it to develop into a hydranth and it either remains undeveloped or produces a stolon."

Besides the assumption of the gradation of material this statement of the hypothesis contains a number of other assumptions. The rapidity of response to the stimulus depends on the direction of gradation of material; a gradation of hydranth-forming substance exists in the hydranth itself. The hydranth takes up nutritive material and so prevents the aboral end from obtaining it, so that this produces a stolon or nothing. But why should the rapidity of response depend on the direction of gradation? What reason is there for supposing a gradation of hydranth-forming substance in the hydranth itself? Why should a stolon develop because the aboral end cannot obtain the nutriment which is taken by the developing hydranth? Does the developing stolon require no nutritive material or does it require a different kind from the hydranth? If the latter, then stolon-formation and logically also hydranth-formation are due not to stolon-forming and hydranth-forming substances laid down in the stems in regular gradation but to nutritive substances occurring apparently anywhere. Moreover, we are told that the formative influence is the stimulus of the water on the free end. If this is the "formative influence" what need is there for hydranth-forming substance?

[1] *Journ. Exp. Zoöl.*, I., 4, 1904, pp. 587–588.

I find it very difficult to obtain any definite conception of the character of the hydranth-forming substance or of the manner in which it acts. Apparently it is not responsible for the size of the structure but only for its characteristic form. In the further development and discussion of the hypothesis a large number of special assumptions are made to meet special cases.

Loeb has recently asserted his belief in the existence of formative substances in connection with regulation and especially as determining polarity. Loeb's view appears to resemble the older Bonnet-Sachs hypothesis of the migrations of particular substances in particular directions. According to Loeb the formative substances are nutritive in character. This hypothesis does not appear to meet the objections to which other hypotheses are open and introduces some new difficulties since conditions determining the localization and distribution of the nutritive material do not seem to be considered.

On the other hand, various results have been obtained in work along this line which hypotheses of formative substances do not seem to me to account for. To mention only a few of these, in *Leptoplana* the larger the portion cut off posteriorly the larger the amount of new tissue formed at the posterior end of the piece remaining. Thus a piece comprising only the anterior third or fourth of the body will produce without being fed five or six times as much new tissue as the anterior four fifths. Yet the "tail-forming substances" and nutritive substances must be much more abundant at the posterior end of the longer piece than at that of the shorter. Again, of two pieces of *Leptoplana* with posterior ends at the same level one containing the cephalic ganglia produces a larger tail than one without them. Why should this difference occur, since the tail-forming substances are the same in amount at the level of the cut and the amount of nutritive substances must be approximately the same in both cases. In *Cestoplana* the new pharynx appears at a given level in a piece containing the ganglia and farther anteriorly in a piece from the same region without the ganglia.

Objection may be made to the citation of these cases here on the ground that they are not pertinent to the matter in hand, in that they are not connected with the problem of polarity. It seems

to me, however, that the relative size of structures produced from different levels and the relative position of intermediate structures are as truly an expression of polarity as the existence of different structures at the two ends, since they must be the result of characteristically different physiological conditions present at the different levels.

Though I have not attempted it, it is possible that with the aid of special assumptions these cases could be made to fit into a formative substance hypothesis, but the value of a hypothesis is to a certain extent inversely proportional to the number of special assumptions required, and there is always danger that a special assumption may introduce more difficulties than it removes.

Moreover, if axial polarity is due to a gradation of substances, we must logically conclude that a gradation of substances from the median line to the lateral margins of the body in both directions exists, for the structural differentiation in these directions is just as truly an expression of "polarity" as is the axial differentiation. This leads us into numerous further difficulties. This lateral gradation must exist in the developing parts as well as in the old, otherwise the differentiation between lateral and median regions could not arise. How, for example, are we to account for the formation of the other side of the body and of a median region in longitudinal pieces of planarians of less than half the width of the body? In whatever manner we may proceed to bring these cases under the general hypothesis certain other special assumptions are necessary. If we say that the formation of the opposite side along the cut surface is due to the excess of margin-forming substance in the piece, how shall we account for the formation of a median region between the two margins? If, on other hand, we attribute the formation of a median region to gradation of the formative substances for this region, supposing them to be in excess at the cut surface, how shall we account for the formation of the opposite side? Furthermore the new marginal region is formed first. Consideration of other experimental data adds further difficulties.

But perhaps enough has been said to show some of the special difficulties in which a hypothesis of formative substances involves

us when we attempt to apply it to the phenomena of form-regulation. Some of the special cases discussed by Morgan will be considered more fully elsewhere in connection with new experimental data.

Such a hypothesis appears to me a totally unnecessary assumption in most cases, probably in all. Moreover, it does not afford a satisfactory explanation of the facts. I have recently made an attempt to account for some of the facts of regulation in a somewhat different manner,[1] and without assuming the existence of a series of substances which seem to me to make comprehension more difficult.

## The Nature of Formative Processes.

The chief peculiarity, and, as I believe, the fundamental error in the hypotheses of formative substances seems to be that they regard the process of morphogenesis as something *sui generis* and not as simply a part of the dynamic or functional activity of the organism. The activities of the organism are considered as two-fold, one group being concerned with the construction of a complex machine, the other with the functions of that machine when completed. According to this view development is primarily a period of construction and not of function. This idea is perhaps a natural consequence of the separation of morphology from physiology. But when we consider the data already at hand it seems impossible to make any such distinction. The organism is primarily and at all times a dynamic or functional complex and the process of morphogenesis is merely an incident, or, in other words, structure is a visible by-product of these activities. In short, it is rather the result of the relations of parts than of any "formative" capacity existing in the single elements themselves, and as regards any given element or unit of the organism the factors of the environment and not the element itself must be, as we have seen, in the final analysis, the real formative factors. These environmental factors may be otherwise designated as the functional or dynamic conditions and we may regard development as primarily a functional process.

[1] *Roux's Archiv.*, XX., 3, 1906.

It is, of course, quite true that the character of the dynamic or functional conditions at any given stage is determined in greater or less degree by the character of the structural consequences of previous activities. These new activities give rise to new structural results until a certain stage is attained, determined doubtless by the complexity of the physico-chemical constitution of the organism, where the mutual determination of structure and dynamic conditions maintains a more or less exact equilibrium for a time. At this stage development is said to be completed. Any or all of the dynamic conditions may in proper environment give rise to conditions visible as structures, hence there are no good grounds for distinguishing certain groups of them or of the substances or structural complexes in connection with which they arise as formative from other merely "functional" groups.

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